TATION BULLETIN 498 June, 1968

DAIRY ADJUSTMENTS IN THE NORTHEAST

An Analysis of Potential Production and Market Equilibrium

DEPARTMENT OF RESOURCE ECONOMICS
NEW HAMPSHIRE AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE

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Preface

In dairy farming, as in many other agricultural industries, a major problem is that of adjusting future production to prospective demand. While many adjustment problems may be considered from the viewpoint of the individual farmer, aggregate production response is the key to this problem. The effects of individual adjustments upon aggregate production must be estimated. This aggregation of individual adjustments to find the production response of an industry has been termed the "micro to macro" approach. It entails developing farm adjustment models and farm situations, solving them for optimal adjustments for a series of prices, and aggregating the resultant output to determine an aggregate supply function.

On the demand side, institutional and transportation costs have tended to preserve the fluid milk markets of the Northeast for local producers. However, there has been substantial net inshipments of manufactured milk products from the Lake States area. The future position of dairy farming in the Northeast depends upon changes in both the supply and demand structures for milk.

This study combines an aggregate supply analysis from the micro to macro approach with a set of synthesized demand relationships which reflect the institutional structure of milk marketing in the Northeast. Two dates, 1960 and 1965, are used in the analysis to point out some of the changes which have occurred over this recent time period.

It should be recognized that this is a *normative* analysis and, as such, is concerned with the potential milk supply if all farmers were to adjust in unison to achieve optimal organization in response to prevailing milk prices, factor costs, and technology. The study thus considers the changes in the potential supply of milk as indicative of changes to expect in actual milk supplies. Parts of this analysis are comparable to the Lake States Dairy Adjustment Study.

Since 1960 State Agricultural Experiment Stations in Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Delaware, and West Virginia and the Farm Production Economics Division, Economic Research Service, U.S. Department of Agriculture, have cooperated in a coordinated study of profitable individual farm and aggregate production adjustments in the Northeast dairy region.

This report is a joint effort of the members of the Northeast Dairy Adjustments Committee. The Committee membership is listed by institution as follows:

NORTHEAST DAIRY ADJUSTMENTS STUDY COMMITTEE

Institutions and Representatives

University of Connecticut	M. W. Kotte* G. A. Zepp* (USDA)
Cornell University	R. Barker D. H. Harrington* (USDA) B. F. Stanton* G. J. Conneman*
University of Delaware	W. M. Crosswhite J. Elterich*
University of Maine	R. N. Krofta* H. B. Metzger E. S. Micka* (USDA)
University of Maryland	J. W. Wysong* J. P. Marshall
University of Massachusetts	B. D. Crossmon E. I. Fuller*
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The Pennsylvania State University	W. L. Barr R. T. Dailey (USDA) R. H. McAlexander* K. H. Myers (USDA) E. J. Partenheimer* S. J. Sheehy
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DAIRY ADJUSTMENTS IN THE NORTHEAST

An Analysis of Potential Production and Market Equilibrium

This study is concerned with the future competitive position among dairymen in the Northeast and between the Northeast and other regions of the country. The dairy industry in the United States is undergoing more rapid change today than at any time in its history. The Northeast has shared in this change. Some of the underlying causal factors are: (1) rapidly changing production and marketing technology, and (2) a gradual change in consumer tastes. At the farm level this has resulted in greater production per cow, more cows per farm, and greater production per farm. In the aggregate, this has resulted in fewer dairy farms, fewer workers, fewer cows, but more total milk production. Introduction of new laborsaving technology has raised productivity per man, but at the same time has made it increasingly difficult for smaller and less labor efficient farms to compete. Changes in the assembly and marketing of milk also have occurred. Bulk tanks have come into widespread use on the farm. Development of super highways has facilitated the use of large tank trucks and reduced the cost of hauling milk to market. Home milk delivery is giving way to distribution through stores. The consumption of fluid milk, fluid cream, and butter has been declining, while the demand for other dairy products has increased. Reconstruction of whole milk, though still in the developmental stage, promises to have an important impact on the industry. "Filled" or "modified" milk as well as imitation "milk" are new products which will affect the consumption of fluid milk.

The rapidity with which these changes are taking place taxes the ability of the dairy industry to adjust. Changes in technology and demand do not affect all farms or all regions equally. A number of so-called adjustment problems have arisen — a cost-price squeeze, low farm incomes, surplus production in some areas, and deficit production in others.

Certain characteristics set apart the Northeast from other major dairy-producing regions. Dairying is the major farm enterprise throughout the region. Proximity to major urban areas has provided farmers in the region with a ready market for milk. A complex pattern of State and Federal marketing orders has grown up in the past three decades with administrative methods varying from market to market.

These conditions pose many questions concerning the future of dairymen in the Northeast. The competitive position of dairymen can be viewed from three levels:

(1) *Inter*farm competition: What farmers in an area will or should continue to produce milk?

(2) *Intra*regional competition: What areas within the Northeast region have a competitive advantage or disadvantage? How is

this influenced by existing institutional arrangements and pricing patterns?

(3) *Inter*regional competition: Will the Northeast continue to hold its share of U.S. production.

Answers to such questions could provide information for farmers and policy makers alike.

Objectives

The study was designed to facilitate investigation of problems in all three of the areas mentioned above. However, attention in this report has been focused upon problems relating to intraregional competition. The primary objectives are:

(1) To estimate the supplies of milk and competitive products (*i.e.*, other livestock and feeds) that could profitably be produced by Northeast dairy farmers in 1965 at varying milk prices.

(2) To estimate the price and quantity of fluid and manufacturing milk eligible under supply and demand equilibrium.

(a) Assuming competitive conditions throughout the Northeast region.

(b) Assuming current institutional restrictions to the (free) flow of milk throughout the region.

The data required to meet these objectives are being used in both farm level and interregional studies.[1] Responsibility for conducting and reporting of farm level investigations has been left to the individual States. This bulletin is primarily concerned with the descriptive and methological phases of the Northeast Dairy Adjustment Study. It describes the region, the methodology, and research techniques and presents the regional data in terms of milk supply functions. Some analysis of data is made as well as a critique of the research procedures.

Description of the Northeast Dairy Region

Characteristics of the Northeast Dairy Region

The eleven Northeastern States included in this region are: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, and Maryland. The large urban population in this area provides an extensive market for both fluid milk and manufactured dairy products for Northeast dairymen.

Dairy farming is the largest agricultural enterprise in the Northeast. Dairying exceeds all other agricultural enterprises in number of

[1] See Appendix B for a listing of other publications which contributed to this study or were developed in conjunction with this regional effort.

farms, use of cropland, and value of farm products sold. Commercial dairy farming in the Northeast accounts for 49 percent of all commercial farms, 60 percent of the cropland on commercial farms, and 45 percent of the value of farm products sold by commercial farms in the Northeast.

Agricultural enterprises represented in the Northeast rank as follows in terms of percentage of commercial farms:[2]

Type of Commercial Farm	*Percent*
Dairy farms	49
Poultry farms	10
Field crop and cash grain farms	9
Other livestock farms	9
General farms	8
Unclassified farms	8
Fruit and nut farms	4
Vegetable farms	3
	100.0

There are areas within the Northeast that contain high concentration of nondairy farms. Notable examples are the Aroostook County, Maine potato area, the Maine and Delmarva broiler area, the Erie-Ontario fruit area, the cranberry area of Southeastern Massachusetts, and the shade tobacco area of the lower Connecticut Valley. Except for these farming areas, dairy farming is the only enterprise which is generally distributed throughout the whole Northeast, and it accounts for the largest proportion of total farm resource use in the region.

Characteristics of Commercial Dairy Farms

Most milk produced in the Northeast comes from specialized commercial dairy farms. They account for 96 percent of the total value of dairy products sold in the Northeast and 40 percent of other livestock products sold.[3] The sale of calves, cull cows, and other joint products of milk production constitute a large proportion of the sales of other livestock and livestock products. Commercial dairy farms account for only 8 percent of all crops sold and only 3 percent of all poultry products sold in the Northeast.

The average size of commercial dairy farms in terms of crop acres varies from a low of 85 acres in Rhode Island to a high of 170 acres in Delaware. The average crop acres per commercial dairy farm for the Northeast is 123. The average number of cows per commercial dairy farm varies from 28 cows in Pennsylvania to 49 cows in New Jersey with an average for the Northeast of 34 cows.[3]

[2] *Source*: U.S. Department of Commerce, Bureau of Census, *U.S. Census of Agriculture, 1964.*

[3] U.S. Department of Commerce. Bureau of Census, op. cit.

Table 1. Total Milk Production, Number of Cows on Farms, and Milk Production per Cow, Northeast Dairy Area, 1956-1966*

1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Total milk production in million pounds										
23,919	23,485	23,705	23,763	24,566	25,274	25,504	25,655	25,747	25,703	24,903
Milk cows on farms in thousands										
3,415	3,327	3,241	3,110	3,106	3,101	3,071	2,981	2,898	2,798	2,654
Milk production per cow in pounds										
7,004	7,059	7,314	7,641	7,909	8,150	8,305	8,606	8,884	9,186	9,383

* Milk Production, Disposition, and Income, U. S. Department of Agriculture, Statistical Reporting Service, Crop Reporting Board, Washington, D. C.

Total milk production in the Northeast increased steadily from 1957 through 1964. The year 1965 marked the first time in eight years that there was a drop in total production. Yet during the period 1957-66 total milk production increased by 6 percent.[4] Over this period cow numbers dropped by 20 percent. Milk produced per cow increased by 33 percent. These changes reflect improvements in the technology of dairy production. The increase in output per cow is the result of better herd management, improvements in forage quality, increased concentrate feeding, and closer culling of herds, as well as improvements in the genetic base of dairy cows.

Other changes in technology which have occurred include the continued substitution of capital for labor through use of mechanical feed, manure, and milk-handling equipment. Greater use of new varieties of hybrid corn and improved hay species also characterize the technological change on Northeast dairy farms.

Market Structure and Pricing

The market structure of the eleven Northeastern States is dominated by six large Federal Order markets. These six markets serve approximately 80 percent of the population of the region. Several States in the Northeast have State milk control boards or commissions which are functionally integrated with the Federal Orders for pricing to the producer. The actual level of prices is determined in various ways in the several marketing orders. Generally, the fluid use price is based on several economic indexes as well as supply-demand criteria. The nonfluid use is often tied to the average United States price for manufacturing milk and the butter price. Prices of the several classes of milk are usually the same in overlapped Federal and State market regions. But since the utilization rates for the various classes may differ between State and Federal destinations, the blend price paid farmers often differs between destinations.

The Federal and State milk orders in the Northeast impose an

[4] See Table 1 and Figure 1.

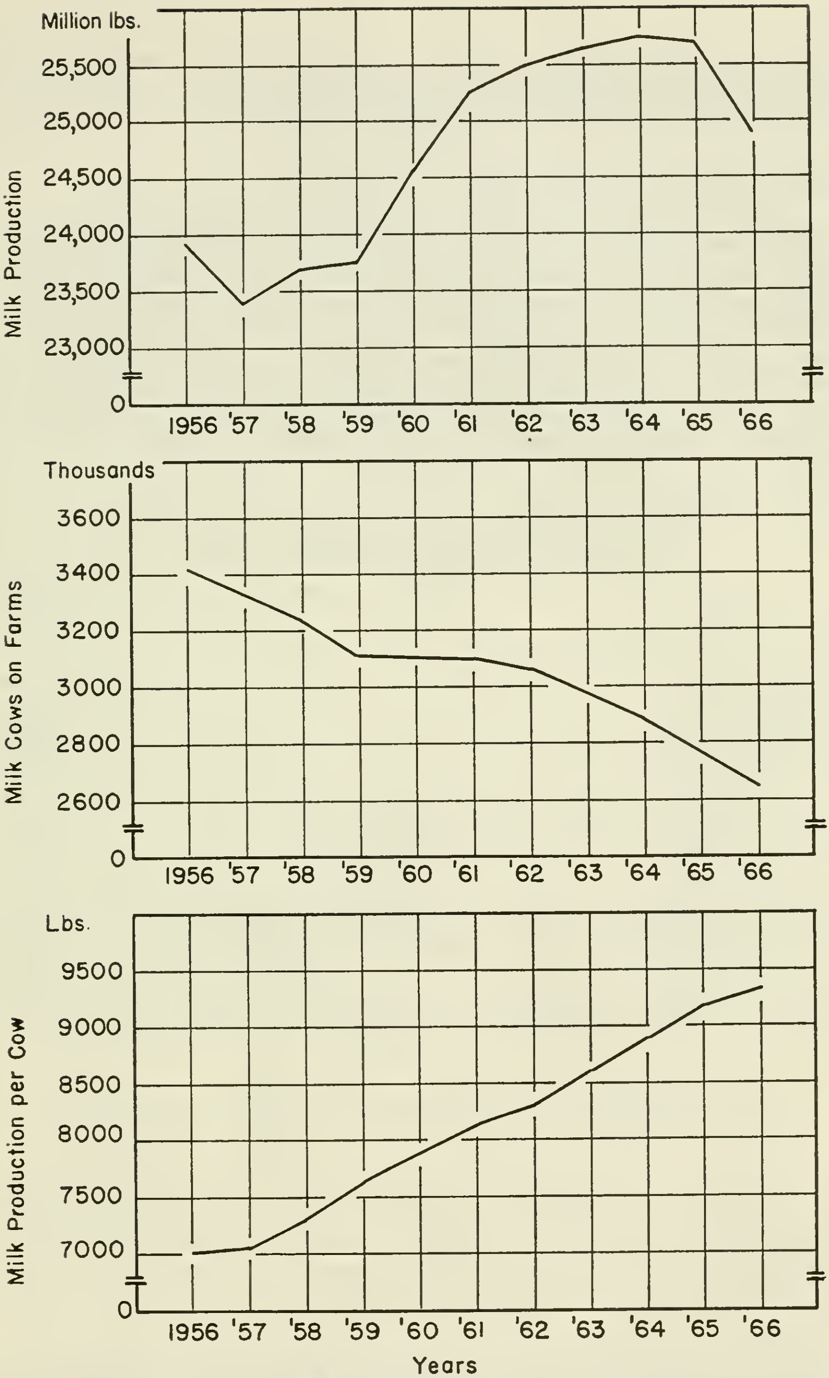

Figure 1. Total Milk Production, Milk Cows on Farms, Milk Production per Cow, Northeast 1956-1966

institutional framework on the movement of milk into and within the region. Changes in market area or source of supply come slowly but this stability is apparently desired by the industry.

Consumption and Utilization

The Northeast is a deficit area in terms of total milk supply. The production of fluid milk is generally adequate to satisfy consumption and no inshipments are made. Much of the supply of manufactured milk products, however, is shipped into the Northeast. Many of the products presently utilized by consumers could not originate in the Northeast since there are limited processing facilities in the area. Table 2 contains estimates of production and utilization of milk in the Northeast for 1965. These data illustrate the current requirements for inshipment of manufactured milk products in whole milk equivalents.

Table 2. Estimated Milk Marketings, Utilization, and Net Inshipments, Northeast, 1965

Item	Pounds
	(millions)
Milk utilization	
Fluid	16,735
Manufacturing	21,980
Total*	38,715
Northeast milk marketings and home consumption†	25,371
Net inshipments of manufacturing and fluid milk	13,344

* See estimates developed for nse by Hsiao, J. C. and Kottke, M. W., *Spatial Equilibrium Analysis of the Dairy Industry in the Northeast Region — An Application of Quadratic Programming*, Storrs (Conn.) Agr. Expt. Sta. Bul. (in process).

† Milk Production, Disposition, and Income, 1965-66, Da 1-2 (67), Crop Report Board, SRS, USDA. (Combined marketings of milk and cream and milk used for milk, cream, and butter on farms where produced.)

Methodology for Estimating Supply Functions

There has been much discussion about the appropriate methods for estimating supply functions. The various approaches are well documented in the literature.[5] The two techniques most commonly used to estimate supply are: (1) the regression of time series data, and (2) budgeting or linear programming. The regression approach is currently

[5] See Earl O. Heady et. al., Ed. *Agricultural Supply Functions*, Iowa State Press, Ames, 1961, or Marc Nerlove & K. L. Bachman, "The Analysis of Changes in Agricultural Supply: Problems & Approaches," Journal of Farm Economics, XLII pp. 531-554, August 1960.

used principally in the analysis of short-run supply response.[6] In recent regional adjustment studies conducted in cooperation with the USDA, supply functions have been estimated through linear programming. The procedure is described briefly as follows:

(1) Stratify the region into areas based upon production opportunities and natural resources.
(2) Sample each area to provide a basis for constructing representative farms.
(3) Construct representative farm linear programming models and solve them with a series of product prices to obtain step supply functions.
(4) Sum the supply functions of the individual representative farms over areas or regions.

This section describes each of the above steps. The procedures employed in this study are for the most part similar to those used in the other regional adjustment studies. A notable exception is the method adopted for the specification of representative farms which is designed to reduce bias in the aggregation of supply functions.

Selection of Areas Within the Northeast

The objective of stratification is to divide the region into farming areas that are homogeneous in terms of such factors as climate, topography, soils, or marketing outlets. Thus, the farms within the area might be expected to have the choice of similar enterprise alternatives, and to be faced with similar yield potentials, prices, and costs. The stratification of the region into areas is followed by the classification of all farms into a smaller number of representative farm groupings within areas. The task of selecting areas and representative farms within areas is closely related.

The Northeast region was divided into 20 such areas based upon the above considerations. These areas are shown in Figure 2 and are identified as follows:[7]

1. Central Maine
2. Southern Maine-Southern New Hampshire
3. Southeastern New England
4. Northeastern Vermont-Northwestern New Hampshire
5. Southeastern Vermont-Southwestern New Hampshire
6. Southwestern New England
7. Northwestern Vermont
8. Southwestern Vermont
9. Hudson Valley
10. Northern New York
11. Oneida, Mohawk, and Black River Valleys

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[6] Effort has been made by Nerlove and others to estimate long-run supply elasticities using time series analysis. See Marc Nerlove, *The Dynamics of Supply*, the John Hopkins Press, Baltimore, 1958.

[7] Urban centers and forest or mountain lands are not considered as production areas.

12. Central Plain of New York
13. Eastern Plateau of New York
14. Southern New York-Northern Pennsylvania
15. Southwestern New York-Northwestern Pennsylvania
16. Southwestern Pennsylvania-Northern West Virginia. Western Maryland
17. Central Pennsylvania-Western Maryland
18. Northern New Jersey-Orange County. New York
19. Southeastern Pennsylvania-Maryland Piedmont and Eastern West Virginia
20. Delmarva Peninsula-Southern Maryland

In Areas 12, 16, 17, 19, and 20, dairy farming is in most instances the dominant enterprise, but competitive alternatives to dairying are numerous. All other areas of the Northeast are characterized by soils and topography better suited to the production of forage than to other crops. Major competition to dairying in these areas is offered by non-farm rather than farm alternatives.

Figure 2. Areas of the Northeast Region Delineated for the Dairy Adjustment Study

Farm Sample and Sampling Procedure

A random sampling process was used in each of the geographic areas identified in the previous section. However, the sampling procedure used varied throughout the region. In the New England States, the dairy farm was the sampling unit. This procedure was justified by the fact that nondairy farms (with potential to shift into dairying) were almost negligible. In the other States the sampling unit was an area of land containing a number of dairy farms. The land segments were drawn randomly, and both dairy and nondairy farms within each of the segments were surveyed. This made it possible to identify "potential" dairy farms.

The specific sampling procedures used in each of the areas are described in detail in the following subsections.

New England (Areas 1-8). In New England, a dairy farm was defined as "a bundle of farm resources containing ten or more milk cows under the single management of one or more operators."

Each State made available a list of dairy farms which represented the universe (*i.e.*, all dairy farmers). The farms were ordered by area and each farm in the area was assigned a number. A random sample was drawn in such a manner as to insure a 2-percent sampling rate in each of the areas (Table 3).

New York, New Jersey, Northern Pennsylvania (Areas 9, 10, 11, 12, 13, 14, 15, and 18). Information required was obtained from a sample drawn by G. J. Conneman for his study of long-run changes in milk production in the New York milk shed.[8] The sampling procedure described here was developed for Conneman's study and was used for the Northeast regional study.

The Conneman study defined a farm or producing unit as a "bundle of farm resources — land, buildings, cattle, and machinery — under the single management or control of one or more operators." The farm universe was defined as all the farms or producing units delivering milk under the New York-New Jersey, Buffalo, or Rochester orders.

Area segments consisting of groups of producers were the *sampling units*. Each of these segments contained approximately 10 farms. To achieve a sampling rate of 2½ percent of the farms, one segment of ten producing units was drawn for every 400 farms. Thus, the number of segments drawn in an area was approximately equal to the number of producing units (established from records of the milk market administrator) divided by 400. All farmers in the segment were interviewed regardless of whether or not they were shipping milk.

In summarizing the procedure, Conneman comments as follows:

"This sampling procedure is the equivalent of dividing the entire milk shed into area segments of approximately ten producing units, and

[8] George J. Conneman. *An Economic Analysis of Changes in Milk Production in the New York Milk Shed*, Progress Report 1, Cornell University, Department of Agricultural Economics, A. E. Res. 135, December 1963.

selecting the appropriate number of segments by a chance procedure that insured geographic distribution of the segments."[9]

Pennsylvania, Maryland, Delaware, and West Virginia (Areas 15, 16, 17, 19, 20). The *producing unit* was a farm classified by census definition. The universe of farms consisted of dairy, livestock, and crop farms, with the exception of specialized fruit, vegetable, and poultry farms. The number of farms (other than specialized) was determined for each township from the 1959 census. The *sampling unit* consisted of a township, or portion thereof, containing more than 10 farms but less than 30 dairy or potential dairy farms. Ideally each segment would consist of 20 farms. However, segments of farms were formed on a township basis because this was the smallest geographical unit for which the number of farms could be estimated. No segments cut across township lines

Sampling units or segments were grouped into blocks. A block consisted of 800 farms in Area 15. 1,000 farms in Areas 16 and 17, and 1.333 farms in Area 19. A block in Area 16 would contain 50 segments

Table 3. Total Dairy and Potential Dairy Farms, Sample Rate and Number of Farms Sampled by Area and State for the Northeast, 1960

Area	State	Number of sample farms	Percent sample rate	Total farms
1	Me.	57	2.0	2,910
2	Me., N.H.	51	3.5	1,473
3	Mass., R.I., Ct.	94	3.1	2,995
4	Vt.	39	2.1	1.859
	N.H.	7	3.4	208
5	Vt.	23	2.4	968
	N.H.	18	2.9	619
6	Mass.	34	2.9	1,168
	Ct.	36	2.7	1,317
7	Vt.	71	3.2	2.224
8	Vt.	19	3.1	615
9	N.Y.	192	3.9	4,960
10	N.Y.	147	2.5	5.880
11	N.Y.	182	2.5	7.280
12	N.Y.	157	2.5	6.280
13	N.Y.	225	2.5	9,000
14	N.Y.	85	2.5	3,400
	Pa.	164	2.6	6.431
15	N.Y.	88	2.5	3.520
	Pa.	100	2.4	4.219
16	Pa.	271	3.0	8,931
17	Pa.	164	1.7	9.647
18	N.J.	77	2.5	3,080
19	Pa.	258	1.7	15.460
	Md.	73	1.4	5.196
20	Md.	75	3.6	2.058
	Del.	32	1.0	3.292
Total. Northeast		2,739	2.4	114,990

[9] Ibid.

(50 x 20 = 1,000). Sample segments were drawn randomly from within blocks. Therefore, the construction of blocks within areas provided a further guarantee of uniform geographic distribution of segments. The sampling rate varied between areas, being 2½ percent in Area 15, 2 percent in Area 16 and 17, and 1½ percent in Area 19.

Farm Survey Data

Farms in the samples were surveyed in the summer of 1961. A total of 2,739 schedules were usable for analysis. The survey was designed to obtain information to permit a description of the resources available for use by the individual farmer. Data were collected regarding cropland and its use, the capacity and use of farm facilities, labor supply, and capital structure. In addition, information was obtained concerning production practices. The survey data provided the basis for developing representative farm models.

Other Data

To complement the farm survey data, production, cost, and price data were assembled from secondary sources.[10] These provided a consistent basis for developing model coefficients which reflect the real difference in the productivity of resources and price differences between the 20 areas studied. Two sets of production relationships were specified. An average set of coefficients was established representing yields with average management and technology used in 1960-61. In addition, a similar set of coefficients was developed representing management and yields associated with the top 25 percent of farmers in 1960-61. These superior production relationships were used in the analysis done in this study.

Long-term real estate credit borrowing capacities had to be developed. The survey schedules provided information concerning farm debt. Real estate appraisals of representative farms by areas were made by members of the Farmers Home Administration. Net worths for study farms were then calculated and borrowing capacities computed.

The price projections used in the Lake States Dairy Adjustment Study provided the basis for the level of prices.[11] Historical price relationships were investigated for each of the 20 areas in the Northeast. Since the milk price was varied in the linear programming analysis, this was the only historical price that was not built into the analysis. Input costs whose levels were not specified were estimated to correspond with the regional price relationship of other items. The intent of these pricing procedures was to simulate historical relationships at an expected 1965 level.

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[10] *Agricultural Planning Data for the Northeastern United States*, Pa. Agr. Expt. Sta., A.E. & R.S. 51, July 1965.

[11] Sundquist, W. B., *et. al.*, Equilibrium Analysis of Income — Improving adjustments on Farms in the Lake States Dairy Region. Minn. Agr. Expt. Sta. Tech. Bul. 246, 1963.

Method of Developing Representative Farms

The research procedure used in this study consists of defining a universe of farms, selecting a number of benchmark farms to represent the universe, and developing optimum plans for these farms at variable commodity prices by linear programming. The programmed results are expanded to obtain an aggregate supply response for the universe. The difference between the aggregate supply response obtained by this procedure and one obtaineed by programming all farms is defined as aggregation bias.

A considerable effort was made to minimize the bias in the supply estimation that could be attributetd to aggregation of benchmark farm data. In the past, the selection of benchmark farms has been done rather arbitrarily, usually on the basis of some common size measure. This procedure, which is done without regard to the relative level of resources on the farms, gives rise to a considerable upward bias in the supply response. This can be easily demonstrated. If farms are classified on the basis of the labor resource, any resulting subgroup may contain some farms that are scarce in labor but have surplus capital, and others on which the resource situation is reversed. When the resources of such farms are averaged, the disproportionalities existing on individual farms tend to be averaged out. Thus, the conventional benchmark will not reflect the restrictive resources of the individual farms, and its expanded output overestimates the aggregate output.[12]

Representative farms were constructed on the basis of estimated homogeneous restrictions.[13] Sample farms from the surveys were grouped according to their most limiting resource in the linear programming model and benchmark farms were defined as the average of resources on all farms within each group. This procedure differs from more conventional methods of representative benchmark farm selection in that it takes into consideration the relative availability of resources and the productivity of resources. Usually farms are classified on the basis of the absolute magnitude of certain resources such as cropland, labor, and number of livestock. The homogeneous restriction method of representative farm selection was used because the supply response of milk based on the farms selected by this method contained a minimum of aggregation bias.

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[12] Frick, G. E. and Andrews, R. A., "Aggregation Bias and Four Methods of Summing Farm Supply Functions," *Journal of Farm Economics*, Vol. 47, No. 3, Pp. 696-700, August 1965.

[13] For a detailed discussion of this technique, see Seamus J. Sheehy, "Selection of Representative Benchmark Farms in Synthetic Supply Estimation," Ph.D. Thesis, Pennsylvania State University, August 1964; Seamus J. Sheehy and R. H. McAlexander, "Selection of Representative Benchmark Farms for Supply Estimation," *Journal of Farm Economics*, Vol. 47, No. 3, Pp. 681-695, August 1965. Also R. Barker and B. F. Stanton, "Estimation and Aggregation of Firm Supply Functions," *Journal of Farm Economics*, Vol. 47, No. 3, Pp. 701-712, August 1965.

Grouping of Farms

Surveyed farms were grouped into six different homogeneous restriction classes for determining benchmark farms. Previous work indicated that a more detailed grouping of farms on the basis of homogeneous restrictions gave only slightly different aggregate supply functions, but the magnitude of the programming time was considerably greater.

In selecting representative dairy farms, some assumptions were made as to how a dairy farm could be defined. In this study it was assumed that any farm selling milk at the time of the survey would be considered a dairy farm. If milk were not being sold from a farm at the time of the survey, such a farm could be considered as a potential dairy farm if it had resources for at least 20 cows. Farms without sufficient resources for at least 20 cows were not included in the programming phase of the analysis.

The six farm groupings were as follows:

Group 1: Nondairy farms, or those with resources for less than 20 dairy cows.

Group 2: Dairy and potential dairy farms on which the forage supply was estimated to permit fewer cows than the winter labor supply or existing dairy building capacity.

Group 3: Dairy and potential dairy farms on which the forage supply was estimated to permit fewer cows than the winter labor supply or total dairy building capacity (existing capacity plus added space permitted by expansion with real estate mortgages), but more cows than with existing dairy building capacity.

Group 4: Dairy and potential dairy farms on which winter labor was estimated to permit fewer cows than the forage supply or the existing dairy building capacity.

Group 5: Dairy and potential dairy farms on which winter labor was estimated to permit fewer cows than the forage supply or the total dairy building capacity, but more than the existing dairy building capacity.

Group 6: Dairy and potential dairy farms on which total dairy building capacity was estimated to permit fewer cows than the forage supply or winter labor supply.

The procedure for grouping of selected farms can be illustrated by the data in Table 4. Information is given on cropland, permanent pasture, soil capacity, dairy building capacity, borrowing capacity, and the winter labor supply on six sample farms for a particular area in the study. This information, along with requirements of dairy cows for these items, provides a basis for classifying each of the farms into groups 1 through 6.

Farm 1 in Table 4 represents a nondairy farm in that the number of cows based on (1) the forage supply that could be produced on the land (Row 8), (2) the winter labor supply (Row 9), or (3) dairy barn

expansion based on loan value of real estate along with the present dairy barn capacity (Row 10) was less than 20 cows. Thus, in accordance with the assumption that a dairy farm would not come into existence with less than 20 dairy cows, Farm 1 is classified as a nondairy farm and placed in Group 1.

Examination of the number of dairy cows possible with the various resources on Farm 2 shows that the forage supply is the most limiting resource, permitting about 25 cows; whereas winter labor and existing dairy buildings would permit approximately 62 and 31 cows, respectively. Thus, this farm would be placed in Group 2.

Table 4. Grouping of Selected Farms on Basis of Homogeneous Resources

Item	Farms classed by homogeneous restriction method					
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
1. Cropland, acres*	59	51	60	49	78	65
2. Permanent pasture, acres*	8	23	10	25	30	14
3. Silo capacity, tons*	90		80	60	70	60
4. Winter labor, hours*	549	1841	1130	808	1126	1405
5. Borrowing capacity†	8178	9738	10616	9972	10500	0
6. Number additional cows possible based on borrowing capacity‡	14.3	17.1	18.5	17.5	18.3	0
7. Existing dairy capacity, number cows*	0	31	27	23	28	20
8. Number cows possible with forage supply§	27.8	24.9	28.3	25.2	39.1	30.4
9. Number cows possible with winter labor supply‖	12.4	61.7	34.5	22.3	34.0	45.0
10. Number cows possible with existing plus added dairy barn capacity¶	14.3	48.1	45.5	40.5	46.3	20

* Based on information obtained from the operator.

† Borrowing capacity is based on 50 percent of owned estimated real estate value less existing mortgages.

‡ Based on borrowing capital divided by $571, the estimated cost of adding building space for the dairy cow and one-fourth replacement.

§ Based on a rotation and forage requirement of dairy animals requiring for each cow and one-fourth replacement, 2.5 acres of cropland, or 5.1 acres of permanent pasture, or 35 tons of silage capacity.

‖ Based on an estimated labor requirement of 26.2 hours of winter labor per cow and one-fourth replacement and 225 hours of fixed dairy labor during this period.

¶ Based on the number of cows permitted with existing dairy building space (Row 7), plus additional cows possible with borrowed funds (Row 6).

NOTE: The resource quantities shown are merely examples for selected firms in one area of the study. The coefficients used in computing the number of cows (including one-fourth replacement for each cow) could differ by areas due to such differences as crop yields, types of forages, length of forage stand, fertilization levels, forage-grain substitutes in the dairy ration, or differences in length of the winter season when estimating total quantity of winter labor.

The estimation of the number of cows permitted by the forage supply is somewhat more cumbersome than for other resources. The forage supply depends upon such factors as the type of forage produced, length of stand, level of fertilization, as well as the possible substitution of forage for grain in the dairy cow ration. Estimation of the most likely forage supply for farms with alternative resource bases can be made by some preliminary programming and determining the types of results obtained. By varying cropland, rather close estimates of forage production and utilization are possible for farms with different resource combinations.

Farms 3 through 6 have been classified into Groups 3, 4, 5, and 6, respectively. Farm 3 would be limited to 28 cows by the forage supply, with cow numbers above that of existing dairy barn capacity but less than total dairy building capacity. Farm 4 would be limited to about 22 cows by the quantity of winter labor, which is less than the existing dairy barn capacity and the forage capacity on this farm. Farm 5 would have enough winter labor for 34 cows, which would allow six more cows that the present dairy building capacity but fewer cows than the forage supply or the total dairy building capacity. Farm 6 would be limited to 20 cows by the total dairy barn capacity, or fewer cows than permitted by the winter labor or forage supplies on this farm.

The farms in different States were classified in this manner. There were variations in such items as length of winter season, yields, and value of property between many areas, resulting in different coefficients than those used for the computations in Table 4. Also, some researchers first classified farm by size of dairy herd before grouping according to the most limiting resource.

Development of Restrictions and Machinery Complements

After the farms were classified, a single benchmark farm was selected for each group excluding the nondairy group. Resource restrictions were then developed for the benchmark farm which were merely averages of the farms within each group. For example, averages were computed for acreages of cropland and permanent pasture, tons of silo capacity, borrowing capacity, and existing dairy housing space. In developing the machinery complements for each benchmark farm, the model incidence on farms in each group was used.

The Linear Programming Models

Linear programming models were designed to compute the optimum organization of representative farms from the standpoint of maximizing profits. Implicit in the construction of the models was the hypothesis that farmers adjust output in response to prevailing milk prices, factor costs, and the state of technology, so as to maximize returns from available labor, land, and capital resources. The linear programming models were coordinated with respect to four major con-

siderations: (1) the comparability of models for the various areas, (2) the choice of production activities, (3) the extent of resource constraints, and (4) the price variability among areas.

Comparability of Models for the Various Areas

The general structure of dairy farms throughout the Northeast region appeared to be sufficiently alike to warrant basically similar linear programming models for all areas. However, each participating state developed its own model so that unique characteristics of each area could be reflected. As a consequence, the various models have some identical equations and some modifications to fit particular area situations. Special care was taken to insure that intraregional productivity differences, if any, would be manifested in the results. All input-output data were carefully scrutinized for intraregional consistency and comparability. Differences in results among areas, therefore, represent the prevailing conditions of each area rather than differences in procedures and assumptions.

Choice of Production Activities

Conditions that usually guide the selection of activities for linear programming models are: (1) the relevant time period, (2) the state of technology, and (3) the degree of specialization.

In this study the problem was to develop a model which was to maximize profits allowing resource use changes and additions that could occur within intermediate run conditions. This temporal condition dictated models designed to depict the production choices available to farmers if they had sufficient time to adjust feeding rates and milk yields, fertilizer rates and crop yields, crop selection and hay procurement methods, dairy cow replacement methods, seasonal labor employment, and barn capacity and silo capacity. Certain areas, in addition, permitted choices between dairy and other livestock enterprises, principally beef and hogs. In calendar time, the study specified 1960 as the base year and initially set 1965 as the target date.[14]

The input-output coefficients used in the model reflect the temporal nature of the problem. Coefficients were used representing management and yields associated with the top 25 percent of the farmers in 1960-61. These relationships were considered to be representative of aggregate farmer response within the time span of the model.

Since most of the New England dairy farmers have few farm enterprise alternatives, the activities for New England models represented specialization in the dairy enterprise. Some diversification is represented by activities included in the models for the other areas of the Northeast. For example, the New York and Pennsylvania models included

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[14] The income results of the models are for a single year's operation. Each adjustment and its corresponding income is considered as a single adjustment to reach static equilibrium, while some activities would likely require several years to reach this equilibrium.

grain production activities besides the beef and hog enterprises mentioned previously.

Extent of Resource Constraints

The major constraints in the model were those pertaining to the representative farm's land, labor, and capital resources. It was assumed for the intermediate run conditions that the farm's 1960 inventory of land could not be expanded. The reason for constraining the land resources of the representative farm to those that existed in 1960 was that while land supply of an individual farm is not actually fixed, the aggregate supply for the region is fixed. From a methodological standpoint, it was requisite to constrain land supply of the individual farm to insure the fixed land supply of the region.

Five labor constraint equations were used; one was for each of four seasonal periods and one for regular hired labor. Full-time hired labor and seasonal labor could be hired in the models.

Winter labor was constrained to that available in the form of the operator's family labor and the regular full-time hired labor on representative farms as of 1960.

A reservation price was placed on the available family labor to reflect the condition that a farmer may not be willing to spend time on some marginal activities unless the return was great enough to cover a minimal reward for this effort.

Funds for capital expansion were constrained to 50 percent of the farm's 1960 real estate value, minus the 1960 outstanding debt.[15] These capital funds could be used for barn and silo expansion. The model was designed to permit expansion in cow carrying capacities of a farm, but limited to an investment ceiling which reflected the credit base of the farm. Funds for annual production were not limited; however, an annual return of 6 percent was required on all production investment capital.

Variable Prices

Two considerations were confronted in regard to price variation. Should only the price of milk vary with all other prices assumed constant, or should other prices vary also? What is an appropriate range of price variation? On the first question, it was decided to variable-price program by varying only the price of milk. For the second question, solutions were obtained for the \$2.80 to \$6.40 per hundredweight range in milk price.

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[15] The survey schedules provided information concerning farm debt. Real estate appraisals of representative farms by areas were made by members of the Farmers Home Administration. Net worths for study farms were then calculated and borrowing capacities computed. If it were determined that a particular farm had a negative borrowing capacity, it was rounded up to zero.

Table 5. Abbreviated Tableau of the Linear Programming Model Used for Area 3*

Constraints, controls, and transfers / Activities	B_i	X_j	Milk sales	Base cows	Variable cows	Feed-milk function	Buy grain	Raise, buy or sell repls.	Buy cows	Add facilities	Additional labor	Interest cost	Sell hay	Buy hay	Hay transfer	Forage crops	New seeding	Sell calves
C_j			c	−c	c		−c	*	−c	−c	−c	−c	c	−c		−c	−c	c
			1	2	3	4–9	10	11–14	15	16–17	18–21	22	23	24	25	26–39	40–41	42
Milk transfers	1		1			−a												
Feed-cow trans.	2			−1	−1	1												
Crop acres	3–6	b														a	a	
Forage transfer	7					a		a						−a	−1	−a		
Pasture control	8–10					−a		−a								a		
Grain transfer	11					a	−1	a										
Hay transfer	12												a		1	−a	−a	
M Base cows	13	b		1														
Cows on hand	14	b			1				−1									
Barn capacity	15	b		1	1			a		−1								
Repl. control	16–18	b		*	*			*										1
Hay control	19–20			+a	+a								a	−a				
Silo capacity	21	b								−1						a		
Labor by qtrs.	22–26	b		a	a			a			−a					a	a	
Seeding control	27–28															a	−a	
Cash reservation	29			a	a			a	a			−a				a	a	
Capital funds	30	b								a								

* In this condensed form the elements only suggest the general relation of activities and constraints. Since some of the rows and columns are combined, some of the elements designated "a" or "-a" may represent several elements. The elements designated "*" represent a combination of positive and negative elements.

A Linear Programming Model for One of the Representative Farms

An illustration of the linear programming model is presented in Table 5. This model was used for Area 3 (Southeastern New England). The abbreviated matrix form describes activities, constraints, and general structure although the grouping together of similar activities and constraints removes some of the details of the model.

The feeding activities (X_{4-9}) represent points on a grain-forage-milk production function and offer a choice in the milk production level ranging from 9,160 to 10,780 pounds per cow. One of the two "cow" activities is for 10 base cows which carry the overhead labor requirements for the whole herd. They are forced into the solution by a high negative C_i value of the disposal activity of the ten cows. The second "cow" activity, called variable cows, offers a choice in the number of cows in the herd. Variable cows are constrained principally by the labor and/or barn capacity, but the barn capacity limit can be overcome by barn construction activities up to the limit of available capital funds, if it is profitable to do so. The model also offers choices of raising or buying replacements (X_{10-14}) and buying or selling hay (X_{23-24}). There are

Table 6. Major Resource Levels of an Area 3, Group 5 Farm Selected for Illustrating the Step Supply Function

Resource levels	Unit	Quantity
Land:		
Total land	Acre	278
Total cropland	Acre	97
Cropland rented in	Acre	48
Permanent pasture	Acre	83
Crop:		
Legume-grass	Acre	30
Grass	Acre	56
Corn silage	Acre	11
Livestock:		
Milk cows	Number	58
Youngstock	Number	22
Building:		
Barn capacity	Head	63
Silo capacity	Ton	528
Labor:		
Family		
Winter	Hour	1,346
Spring	Hour	1,634
Summer	Hour	1,868
Fall	Hour	1,623
Regular hired		
Winter	Hour	528
Financial:		
Real estate value	Dollar	43,500
Real estate loans	Dollar	5,500
Borrowing capacity	Dollar	16,250

seventeen forage-producing activities (X_{25-39}) and (X_{40-41}) offering selections of corn silage at two fertilizer rates, alfalfa hay at two lengths of stand and two fertilizer rates, clover grass at two fertilizer rates, mixed grass at two fertilizer rates, and two lengths of stand and perminent pasture at two fertilizer rates.

Altogether, the model offers numerous possibilities of different combinations of inputs and outputs that Area 3 dairy farmers typically would face under the intermediate run conditions of this study.

Table 7. Milk Supply Function, Area 3 Representative Farm, Group 5

Price of milk per cwt.	Optimum milk output in cwt.	Number of cows	Annual grain feeding level in pounds	Dairy cow replacement program
$2.30	3866	42	1500	raise, sell
3.01	4050	44	1500	raise, sell
3.19	4299	47	1500	raise, sell
3.20	4423	48	1500	raise, sell
3.41	4906	54	1500	raise, sell
3.46	5037	55	1500	raise
3.50	5074	55	1500	raise
3.74	5187	55	1750	raise
3.78	5371	56	1750	raise, buy
3.83	5442	57	2000	raise, buy
4.02	5563	58	2000	raise, buy
4.03	5577	58	2000	raise, buy
4.15	6057	58	2000	raise, buy
4.48	6291	63	2000	raise, buy
4.49	6300	63	2000	raise, buy
5.02	6305	63	2500	raise, buy
5.03	7090	71	2500	buy
5.19	7500	73	3000	buy
5.21	7773	75	3000	buy
5.42	9158	89	3000	buy
5.46	9221	89	3000	buy
5.71	9775	92	3500	buy
6.07	10017	94	3750	buy
6.45	10120	94	3750	buy
6.50	10120	94	3750	buy

Linear Programming Solutions for a Representative Farm

A representative farm from Area 3, in this case one in the Group 5 category, with resources such that winter labor is the most effective constraint, can illustrate the model. As surveyed, the dairy herd had 58 cows which made it about 20 cows above average size for Area 3. The major resources of the farm are shown in Table 6. The variable-price programming resulted in a range of optimal annual milk outputs from 386,600 to 1,012,000 pounds (Table 7). In general, milk prices below $3.40 per hundredweight have optimized solutions involving less than 50 cows, the lowest grain feeding level, the sale of

some hay, and the sale of some replacement stock. At milk prices between \$3.40 and \$4.40, the solutions indicate 58 cows (the representative farm's 1960 number of cows on hand), the second lowest grain feeding rate and the raising of replacements. If milk price ranges between \$4.40 and \$5.00 per hundredweight, the farm should operate at full barn capacity (63 cows). As the price gets higher, the optimized solutions call for significant adjustments in the farm's operations. Expansion of barn facilities to permit up to 94 cows, increase in feeding rates to the highest levels, and a change to a "purchase replacements" program are indicated. The nature of the step supply function suggests that this farm should be relatively sensitive to price changes under intermediate run conditions (Figure 3). The implication of the function is that the potential milk supply forthcoming from the representative farm of Area 3 at a price, say \$5.20, should be about 44,000 pounds greater than if the price were \$1.00 less and the price of milk and prices of other factors were expected to hold long enough for the intermediate run conditions to prevail.

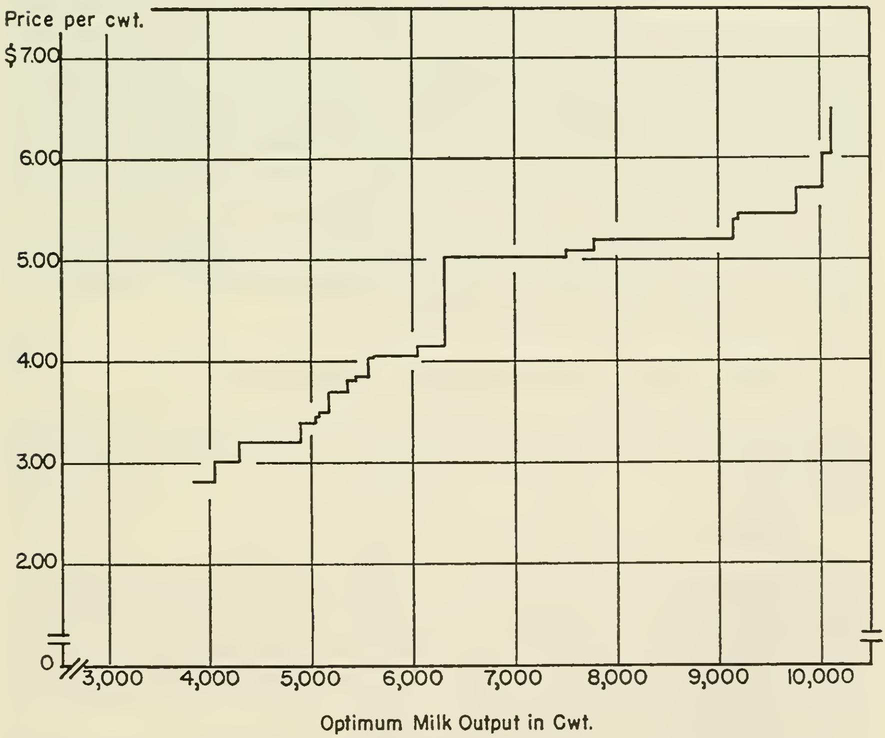

Figure 3. Milk Supply Function, Area 3 Farm, Group 5 Category

Area and Regional Aggregate Milk Supply

Resource Bases for Area and Regional Milk Supply, 1960 and 1965

Stepped supply functions were developed for each group of farms following the procedure just described for the Group 5 farm in Area 3. Milk outputs at the several planned milk prices were multiplied by appropriate farm group weights to obtain each of the 20 area step supply functions. The number of farms in each of the six homogeneous restriction classes formed the basis for the expansion factors of the sample in each area.[16] Thus, the total number of dairy and potential dairy farms in 1960 represents the 1960 resource base. The regional milk supply function for 1960 was obtained by adding the 20 area milk supply functions at the several milk price levels. Only one type of supply function is needed because virtually all milk produced in the Northeast is eligible for fluid Class I use.

The procedures for estimating the area and regional aggregate milk supplies using the 1965 resource base was the same as that using the 1960 resource base. The considerable decline in dairy farm resources that occurred in the period 1960-65 was taken into account.[17] This net exit of farm resources was incorporated in the 1965 resource base through a decrease in the total number of dairy and potential dairy farms based on census and other secondary sources of data. This procedure would be consistent with the classification methods used in developing the representative farms only if changes in numbers of each homogeneous grouping of farms were proportional to total farm number change. Through resurveying and reclassifying, it was found that proportional changes in numbers of farms did occur in each grouping of sample farms over the 1960-65 period. Thus, it was possible to update to the 1965 resource base of farm numbers without reweighting the homogeneous catagories of the sample farms.[18].

Area Supply Functions with 1960 and 1965 Resource Base

Supply functions for each of the 20 Northeast areas were computed using the procedures just outlined. These supply functions are based on superior technology and profit maximizing principles and, therefore.

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[16] See Table 3 for sampling and total farm numbers in 1960.

[17] It is recognized that farm numbers declined more than farm resources in this 1960-65 period. The research methodology of the micro to macro approach makes it difficult to deal with aggregates of resources in an area such as total cropland or hay supply for purchase or for sale. This is discussed in the section of the manuscript describing the linear programming model. The individual representative farm groups were optimally planned based on resource availability at the time of the 1960 survey. The milk supplies from this programmed sample were expanded to the universe of farm numbers for the years 1960 and 1965.

[18] One of the limitations of the homogeneous restriction method of grouping is its incompatibility with conventional farm descriptive materials such as the census. Secondary data sources do not permit development of farms that can be sorted on resource restrictions.

represent potential rather than actual supply. Area supply functions for the 1960 farm numbers resource base are presented in Appendix Table 2. The same basic supply relationship expanded using the 1965 farm numbers as the resource base is shown in Appendix Table 3.

Both sets of area supply functions were summed to construct the regional supply functions which now will be considered.

Regional Supply Functions

The area supply functions shown in Appendix Tables 2 and 3, if added at the several prices, form two regional supply functions. These regional supply functions reflect no area price differentials. However, location differences of supply and consumption have given rise to a pattern of regional farm prices which reflect milk transportation costs from producer to consumer. By introducing this pattern of transportation difference using actual farm prices, two more regional supply functions may be developed using the information in Appendix Tables 2 and 3.

Regional Supply Functions with no Area Farm Price Differentials and 1960 and 1965 Resource Bases

The supply functions without price differentials between areas were developed through simple summation of the 20 area supply functions. These summations assume that an equal farm price for milk exists for the Northeast. The area supply functions were calculated by using the resource bases of 1960 and 1965 (Table 8). These supply func-

Table 8. Northeast Regional Supply Function, 1960 and 1965 Resource Base, Without Area Price Differentials

Price	Resource base	
	1960	1965
	(Thousand cwt.)	(Thousand cwt.)
$2.80	219,357	169,832
3.20	284,543	219,024
3.60	312,055	240,086
4.00	361,590	278,233
4.20	381,473	293,750
4.40	390,949	301,465
4.60	404,132	311,829
4.80	413,521	319,041
5.00	423,442	326,530
5.20	429,563	331,322
5.40	438,707	336,697
5.60	443,634	340,296
5.80	446,624	342,616
6.00	450,718	345,287
6.20	453,054	347,609

tions show the quantity of milk which would be forthcoming if: (a) all farmers in the Northeast made optimal adjustments; (b) intermediate run conditions prevailed; (c) a management level equivalent to the top 25 percent of farmers in 1960 was employed; (d) the resource base used was that of 1960 or 1965; and (e) all farmers received the same price for their milk. These regional supply functions depart from the assumptions of the perfect competitive model in that transportation costs are neglected.

Regional Supply Functions with 1965 Milk Price Differentials and 1960 and 1965 Resource Base

Price differentials between areas in the Northeast reflect differences in transportation costs and institutional arrangements. The 1965 milk price differentials between areas were used to determine aggregate supply functions (Figure 4). The average 1965 milk price in the Northeast was $4.84. The nearest programmed price, $4.80, was selected as the base price. Prices in Areas 8, 12, 16, and 17 approximated this average price. Supply schedules were adjusted such that prices in all other regions would reflect the 1965 price differences. The base price used for each of the 20 areas and the differential from the $4.80 base price is shown in Table 9 and Figure 4. Then simple summation over quantities so arrayed yield the regional supply function. The resulting supply functions are described in Table 10.

These regional supply functions, constructed with area price differentials, have all the implicit and explicit assumptions associated with length of run of model, normative optimizing principles, and high level management associated with the procedures of this study. The advantage of these functions is that they reflect price advantage of one area over another. However, they are not supply functions in the competitive sense because they incorporate existing institutional arrangements, *i.e.* milk market orders.

Point Elasticities of Supply with 1960 Resource Base and 1965 Area Prices

Considerable interest is always expressed in comparing the relative responsiveness of milk output to price change. To do this, elasticities of supply for each area were estimated. First, a simple linear regression equation was fitted to the observed points along the step supply functions. The slope of the regression equation for each area was multiplied by each area price and the result divided by the quantity of milk estimated to be produced at that price. These estimates of supply elasticities for the 20 areas are shown in Table 11.

Among the 20 areas those with more production alternatives for dairy—such as hogs and beef in Southeastern Pennsylvania, Maryland, and Delaware and crop production in Western New York State—elasticities were greater than for areas where there were few livestock or crop alternatives. Examples of areas with few alternatives include: Area 2, Southeastern New Hampshire and Southwestern Maine: Area

Figure 4. Estimated Farm Milk Prices, 20 Areas of the Northeast, 1965

10, Northern New York; and Area 13, the New York Plateau. The greatest response in milk output to a change in price was indicated for Areas 3, 6, 12, 19, and 20 (Massachusetts and Connecticut, Western New York State, Southeastern Pennsylvania, and Delaware and Maryland). In these areas, milk output was up to four times more responsive to price than in those areas with the fewest alternatives.

Supply functions and elasticities are affected by time considerations. Implicit in the models is sufficient time for cropping systems to be changed and additional capital invested in barns and silos. Explicit in the methodology used, all farms are assumed to make the optimal adjustments to their alternatives. These supply functions represent potential supplies of milk forthcoming from farms based on the 1960 and 1965 resource bases.

Table 9. Prices and Price Differentials, 20 Areas in the Northeast, 1965

Area	Estimated area average farm prices, 1965	Differentials from $4.80, the assumed base price
1	$5.20	$+0.40
2	5.40	+0.60
3	5.60	+0.80
4	4.60	−0.20
5	5.20	+0.40
6	5.60	+0.80
7	4.60	−0.20
8	4.80	0.00
9	5.00	+0.20
10	4.00	−0.80
11	4.20	−0.60
12	4.80	0.00
13	4.20	−0.60
14	4.20	−0.60
15	4.40	−0.40
16	4.80	0.00
17	4.80	0.00
18	5.20	+0.40
19	5.20	+0.40
20	5.00	+0.20

Table 10. Northeast Regional Supply Functions, 1960 and 1965 Resource Base, with Area Price Differentials

Price	Resource base	
	1960	1965
	(Thousand cwt.)	(Thousand cwt.)
$4.20	368.270	282,858
4.40	382.868	293,491
4.60	397,011	305,145
4.80	412.923	317.639
5.00	425.299	327.272
5.20	431.942	332,983
5.40	438.711	336.995
5.60	443.280	339.954
5.80	448.201	343.959

Table 11. Point Elasticities Based on Linear Equations Derived from Stepped Supply Function, 20 Northeast Areas, 1960 Resource Base, 1965 Estimated Area Prices

Area*	Intercept "a" value	Area price	Quantity of milk at area price	Slope "b" value	Elasticity†
	(1,000 cwt.)	(Dollars)	(1,000 cwt.)	(1,000 cwt.)	
1	2,135	5.20	8,115	1,150	.74
2	1,735	5.40	5,785	750	.70
3	520	5.60	13,400	2,300	.96
4	3.960	4.60	10,055	1,325	.61
5	2,120	5.20	8,672	1,260	.76
6	685	5.60	12,081	2,035	.94
7	4,940	4.60	12.530	1,650	.61
8	960	4.80	3,744	580	.74
9	6.855	5.00	23.855	3,400	.71
10	14.130	4.00	21,930	1,950	.36
11	13,815	4.20	32,043	4,340	.57
12	−17,050	4.80	21,302	7,990	1.80
13	14.220	4.20	28,458	3,390	.50
14	12.235	4.20	32,185	4.750	.62
15	8,070	4.40	25,868	4,045	.69
16	5.430	4.80	25.638	4,210	.79
17	3.340	4.80	22,108	3,910	.85
18	4,500	5.20	17.682	2.535	.75
19	4.285	5.20	66,243	11,915	.94
20	−1,100	5.00	1,350	490	1.81
Total	88.205	4.84	397.902	63.987	.78

* See Figure 4 for location of areas.

† $\text{Elasticity} = \dfrac{(\text{area price})\ (\text{"b" value})}{(\text{quantity of milk at area price})\ (\$1.00)}$

Evaluation of Micro to Macro Research Procedure for Estimating Supply Functions

It is appropriate to make some evaluation of the synthetic estimation of aggregate milk supply response. The 1965 Northeast milk production was reported to be 25,371 million pounds (Table 2). The most comparable milk output using the 1965 resource base with area milk price differentials was computed to be about 32,000 million pounds (Table 10). Some discrepancies between observed and computed amounts were anticipated since the research procedure was not designed to be predictive in the sense of defining what farmers would do. Rather. the high level of estimated supply was due largely to the optimizing

assumptions of the model and the superior level of technology. Other factors also influenced the results. These will now be discussed to aid in planning future research efforts in this area of research and to indicate contributions of the research to research methodology and procedures.

Some Limitations of the Generalized Approach

1. The summation of linear programmed firms' supply functions does not represent aggregate behavior. The normative methodology assumes all farms adjust output to price in unison on the basis of profit maximization. Each representative firm operates at optimum output in a riskless environment and represents identical behavior for a whole group of individual firms. This, of course, does not agree with reality since actual farms are, at any time, in all stages of growth or adjustment.[19]

2. Interfirm transactions cannot be dealt with in the micro to macro buildup as long as the model firms are programmed as independents. Interfirm "buy" activities of such items as hay are handled separately from the "sell" activities, and there is no reason to expect a balance by chance for an area. All schemes of constructing aggregate constraints on total use of land, total cow numbers, and intermediate products such as hay are somewhat arbitrary as long as model firms are programmed independently.

3. Representative farms and their expansion to area supply does not explicitly take into account the important supply shifters associated with the size of the resource base. Difficulties involve the influence of exit and entry of farms in the resource base and the influence of the family life cycle upon farm growth. Production goods with a longer life than one production period were restricted to available credit. There is no reason to expect that all firms would treat the "capital" input process the same. This growth concept hinges on the "stage of life" of the firm. In a micro to macro buildup, farms might better be classified in their "stage of life" to see if they would expand or even replace capital assets.

4. An aggregation error is associated with the micro to macro aggregative approach to regional supply analysis. In general, some method of handling aggregation error must be devised for each study.

5. The micro to macro building process is extremely time consuming. Difficulties are encountered in developing input-output coefficients which are compatible and consistent with the assumption of the analysis.

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[19] Dr. Marvin W. Kottke defined this limitation and called it the "Rockette Theory of Adjustment."

6. There is a "dated time" problem. There must be compatibility between the length of run, the dates of the resource bases, and the implicit dates of the level of technology so that results will be meaningful.

7. The length of run incorporated in the model is of crucial importance. Shortening the length of run results in more inelastic supply estimates and accentuates the effect of supply shifters on milk output. Extending the length of run accentuates the problems associated with input-output coefficients, resource bases, and relevant alternatives in specifying the model.

Particular Problems Associated with This Study

1. It is recognized that the input-output coefficients of the model represent a higher level of response than was projected for 1965. Indications are that the coefficients used were closer to the expected 1970 level of technology.

2. Computer capabilities for handling very large matrices were not available when the programming for this study was started. For this reason, multiple farm models with transfer activities and aggregate constraints could not be handled.

3. The updating of the resource base from 1960 to 1965 was not planned in the original scheme but was added as a superstructure when its importance was discovered. A preferable procedure would be to have an observed 1965 resource base rather than a resource base updated from Markov Chains or frequency distribution data.

4. A more efficient way of dealing with aggregation errors might be to estimate their magnitude and correct for the bias. Much meaningful economic detail is lost in the methods of sorting farms to minimize aggregation error. The homogeneous restriction method of grouping farms is exceedingly difficult to trace through time. It advantages in reducing aggregation error are offset by the difficulties in projecting the distribution of farms between homogeneous restriction categories.

Contributions of Micro to Macro Research

Besides assessing potential supply, the micro to macro approach has many useful joint products. Among these are input-output data and models suitable for farm management analysis. The major research effort in developing the input-output relationships and models can be used directly in studies of optimal organization and adjustment of farms.[20]

This study focused the efforts of many research workers. In that way new insights were gained and significant contribution to methodology made. One excellent illustration is the definitive treatment of

[20] See Appendix A for a partial listing of studies which pertain to this regional research project.

aggregation bias. New formulation of programming models of a temporal nature with interfarm relationships were developed. Models of a more predictive nature were tested and future research planned. Of major importance is the contribution of this effort to a better understanding of the influence of policy on supply.

Some Applications of the Aggregate Milk Supply Functions

The aggregate supply functions indicate the quantities of milk which farmers could produce within the framework of the research procedures. Various types of equilibrium analyses can be made using the area or the regional supply estimates. A spatial equilibrium analysis for the Northeast has been completed by Hsiao and Kottke.[21] Their analysis made use of the area supply functions. A limited aggregate regional analysis of supply-demand equilibrium will be made in this report. To do this, some analysis of the nature and scope of demand for milk in the Northeast must be made.

Demand Functions

Demand functions for fluid and manufacturing milk were estimated for the 20 study areas. These estimates were developed specifically for the Northeast Dairy Adjustment Study since there were no estimates of slope or elasticity of demand functions on a regional or area basis.

The procedure involved determining per capita consumption of fluid and manufacturing milk on a national basis. These national per capita consumption data were modified for the Northeast region based on information from the 1955 Food Consumption Survey, published in "Food Consumption of Households," Reports 1 and 6, by the United States Department of Agriculture, 1956. Per capita milk consumption was refined by incorporating differences among areas in the proportion of urban, rural nonfarm, and rural farm populations and per capita income.[22]

This procedure yielded a price-quantity observation on a per capita basis for each of the 20 Northeast areas and two consumption areas for both fluid and manufactured milk products. (See Appendix Table 1.) This determined one point on each of the demand functions. Linear demand functions were forced through these points using slope

[21] Hsiao, J. C. and Kottke, M. W., op. cit.

[22] Based on the income elasticities of 0.16 for fluid milk and 0.17 for manufacturing milk developed and presented by Daly, R. F., *Agriculture in Years Ahead*, a talk presented at the Southern Agricultural Workers Conference at Atlanta, Ga., Feb. 3. 1964. These procedures take into account variations in income due to regional location and differences in price of substitutes based on historical price ratios.

coefficients estimated by Brandow.[23] Area demand functions for both fluid and manufacturing milk were developed by multiplying per capita demand functions in each area by population within the area. The demand functions reflect the price-quantity relation given the 1965 income pattern, price of substitutes, and population size and composition in each area. [24]

Regional Demand Function Under Competitive Conditions

A regional demand function for fluid milk was determined for the Northeast States by summation of the 20 individual area demand functions. The regional demand function for manufactured milk was obtained by following the same procedures. A combined regional demand for manufacturing and fluid milk was developed by horizontal

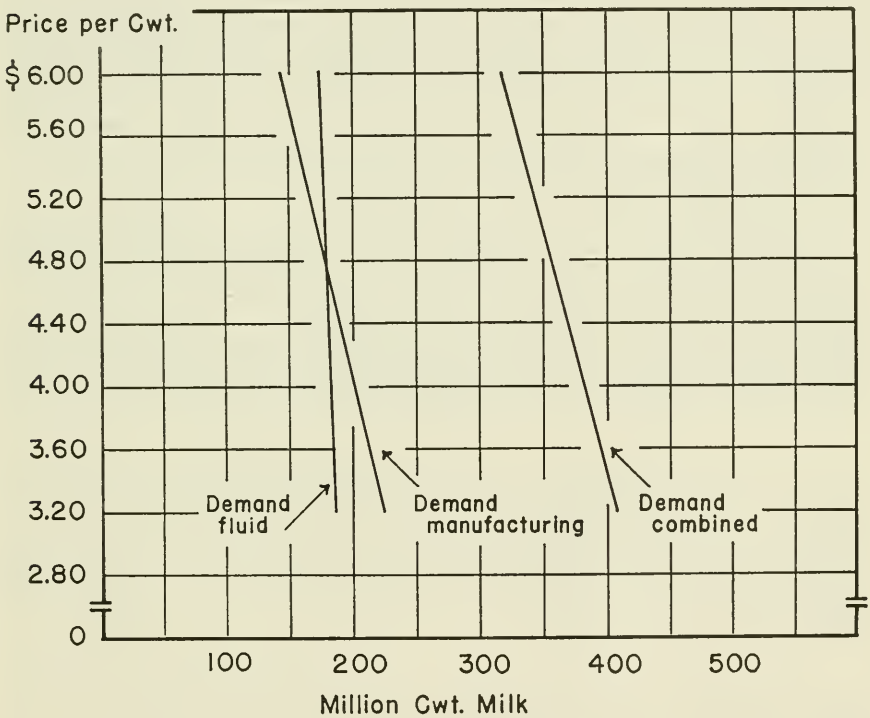

Figure 5. Linear Demand Functions for Fluid Milk, Manufactured Milk and Combined Demand, Northeast, 1965

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[23] Brandow, G. E., Interrelation Among the Demand for Farm Products, Implication for Control of Market Supplies, Pa. Agr. Expt. Sta. Bul. 680, 1961.

[24] Dhillon, P. S., Projected Estimates of Demand for Fluid and Manufacturing Milk in the Northeastern United States, A. E. and R. S., Department of Agricultural Economics & Rural Sociology, The Pennsylvania State University, 1968.

summation of these two linear demand functions. The resulting demand functions are shown in Figure 5. By horizontally summing these two demand functions, the classified pricing provisions are neglected and a single price for both fluid and manufacturing milk is assumed. This assumption is not representative of the market in the Northeast.

Regional Price-Quantity Disappearance Curve Under Classified Pricing

Where most milk produced and sold in the Northeast is included under either a Federal or State market order. a price-quantity relationship reflecting this market structure would be more meaningful than the combined linear demand function.

A price-quantity relation which reflects the existing classified pricing system was developed. The regional demand function for fluid milk was used to represent the demand for fluid milk for the region. An infinitely elastic demand curve was assumed for manufacturing milk. In other words, an unlimited quantity of milk could be sold at the manufacturing price and the quantity of manufacturing milk produced in the Northeast would have no influence on its price.

Under the classified pricing structure there exists a demand function similar to that assumed for fluid milk. A price for fluid milk is set in each market under the market order by a milk control board (or as determined at hearings or some method of formula pricing). Hence, the price paid farmers for fluid milk is determined by administrative decree. The quantity sold is determined by the quantity of milk consumers are willing to purchase at this administratively established price.

Support for a perfectly elastic demand for manufactured milk can be found in the performance of the manufactured milk market. This market is national in scope. The Northeast supplies a very small portion of the total quantity. In fact, the Northeast is a substantial deficit area; it imports about one-third of the manufactured products (in whole milk equivalents) consumed. Thus, the Northeast output of manufactured milk has negligible influence on the price.

Two more points about the price of manufactured milk should be made. First. the price of manufactured milk is also administratively determined in many Northeastern markets and is frequently based on the U.S. average manufacturing milk price. Second. the Federal Government price support activities for milk products effectively establishes a price floor for manufactured milk. If the fluid demand and manufacturing demand functions described above are evaluated using a milk price blend formula, a line resembling ABC. Figure 6. can be traced. Curve ABC represents the price that farmers would receive if various quantities of milk were produced.

The blend price formula was employed to determine the fluid milk price and utilization with the 1965 blend price, manufacturing price, the demand function for fluid milk, and total milk consumption.[25] The estimated price-quantity curve describes how prices received by farmers would vary as quantity of milk varies under the existing blend pricing system with the demand relationships of 1965.

Implications of the Price-Quantity Equilibrium

The four supply relations and two demand situations provide a total of eight price-quantity equilibrium situations to be analyzed. These eight price-quantity equilibrium components are shown in Figure 7 and Table 12. For comparison, the weighted average price and quantities produced in 1965 and the departures from each of the eight estimated equilibrium prices and quantities are included. The closest to 1965 is Equilibrium No. 9, the one developed on the basis of the classified milk market structure with blend price relationship confronting farmers and a supply function that reflects the 1965 resource base and transportation differentials between the 20 areas in the Northeast.

Most outstanding in the analysis of the eight estimated equilibrium situations is the error in estimating quantity when supply functions were based upon the 1960 resource base. This error was sizable for both demand situations and both supply assumptions. See Equilibriums 2, 3, 6, and 7 in Table 12 and Figure 7.

The use of the demand function developed by linear summation also introduced a source of error. For example, Equilibriums 4 and 5 for supply function with the 1965 resource base in which the demand function assumes away classified pricing and inshipments of milk.

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25 The standard blend price formula is: $P_B = \dfrac{P_1Q_1 + P_2Q_2}{Q_1 + Q_2}$

However in developing the price-quantity disappearance curve, P_B, P_2, and $Q_1 + Q_2$ are predetermined. The problem is to find the Class I Price, P_1, and Class I utilization, Q_1, such that the price-quantity disappearance curve will pass through the point.

Substituting the linear demand function relating Q_1 to P_1, and solving by the binomial theorem yields:

$$P_1 = \frac{-(a\text{-}bP_2) + \sqrt{(a\text{-}bP_2)^2 - 4b(P_2Q_t - aP_2 - Q_tP_B)}}{2b}$$

Where:

P_1 = Price of Class I (fluid) milk
P_2 = Price of Class II (manufacturing) milk
P_B = Blend price
Q_1 = Quantity of milk for Class I (fluid) use
Q_2 = Quantity of milk for Class II (manufacturing) use
$Q_1 + Q_2$ = Total quantity of milk, Q_t
$Q_1 = a + bP_1$ = Demand function for Class I milk

Two major implications are observable from this analysis. (1) Changes in resource bases and shifts in technology, commonly called "short-run supply shifters," are more important in determining quantities supplied in the Northeast than is the elasticity of the supply functions as determined by this study. This is true even in the intermediate time period. The importance of a supply shifter is clearly seen in Figure 7 when the supply functions for the 1960 resource base are compared with the supply functions for the 1965 resource base. (2) The total supply *potential* for milk in the Northeast declined considerably between 1960 and 1965 due to the decline in the resource base. It is doubtful that new technology has been developed to offset this decline in *potential* due to loss in resource base. In spite of this, there exists a substantial *potential* for expansion in milk supply if all dairymen adopted the top 25 percent technology available to them in 1960.

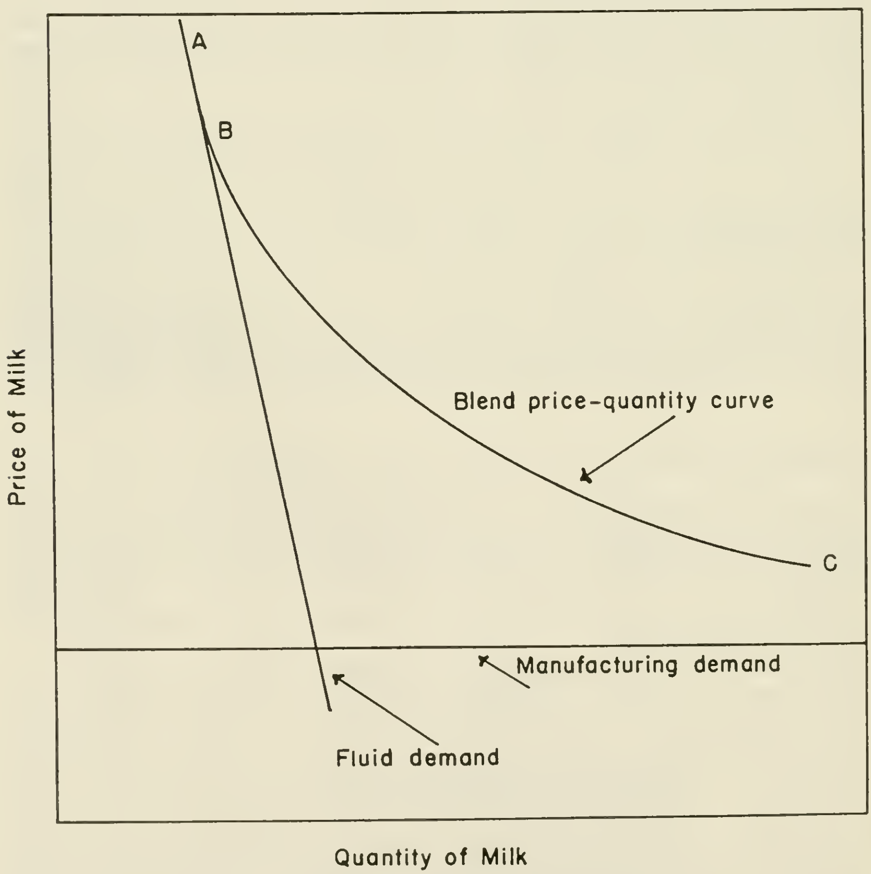

Figure 6. Theoretical Fluid Demand, Manufacturing Demand, and Blend Price-Quantity Curve

Table 12. Summary of Regional Supply-Demand Relationships and Comparison with Actual 1965 Price and Disappearance

Location number on Figure 7	Demand situation: Linear summation	Demand situation: Price-Quantity disappearance	Supply situation: No area price differentials Resource base 1960	No area price differentials Resource base 1965	With area price differentials Resource base 1960	With area price differentials Resource base 1965	Equilibrium: Price	Equilibrium: Quantity	Departure from 1965: Price Actual	Price Per-cent	Quantity Actual	Quantity Per-cent
								(Mil. cwt.)			(Mil. cwt.)	
1 (1965 actual)			....	....	....	....	$4.84	253.7	$.00	...	0.0	....
2	X		X	....	....	....	4.20	378.0	—.64	—13	+124.3	+49
3	X			....	X	....	4.30	374.0	—.54	—11	+120.3	+47
4	X					X	5.42	338.0	+.58	+12	+84.3	+33
5	X			X			5.46	336.0	+.62	+13	+82.3	+32
6		X	X				4.28	384.0	—.56	—12	+130.3	+51
7		X			X		4.32	376.0	—.52	—11	+122.3	+48
8		X		X			4.55	309.0	—.29	—6	+55.3	+22
9		X				X	4.58	302.0	—.26	—5	+48.3	+19

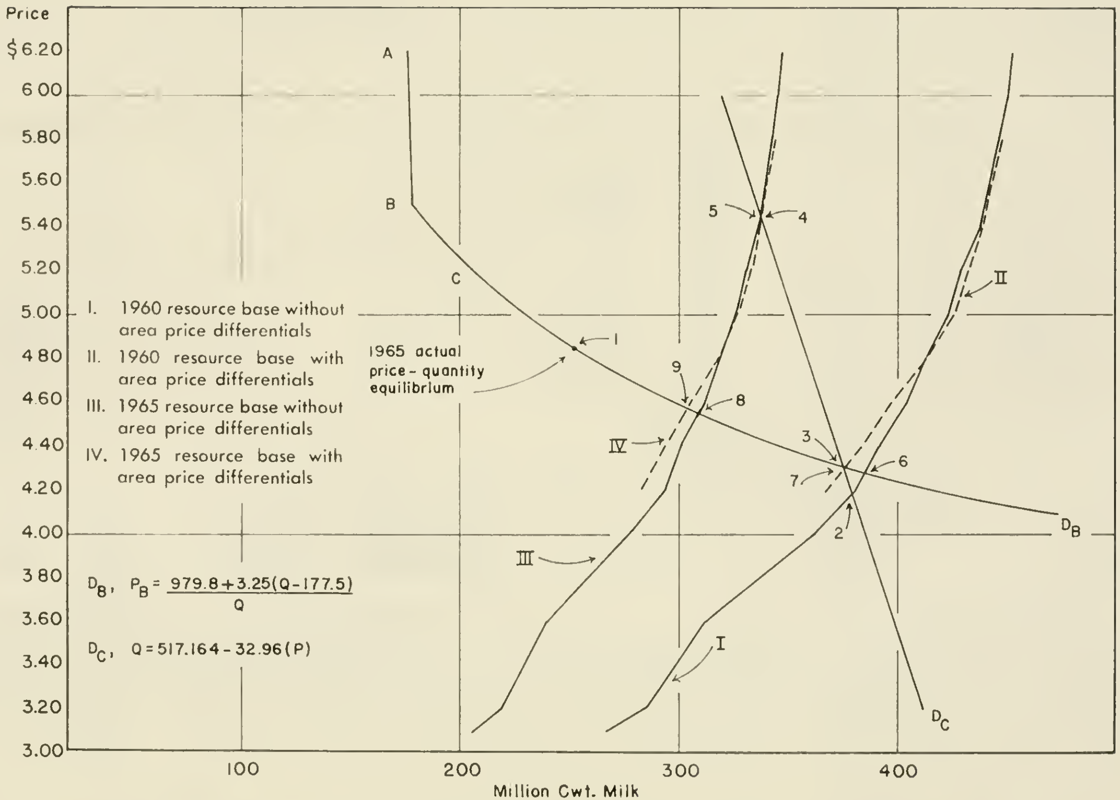

Figure 7. Regional Aggregate Milk Supply Functions, Demand Functions, and Price-quantity Equilibrium Points

APPENDIX A

Appendix Table 1. Estimated Demand Functions for Fluid and Manufacturing Milk for 1965

Area	Fluid milk		Manufacturing milk	
	Quantity intercept 'a'	Slope coefficient 'b'	Quantity intercept 'a'	Slope coefficient 'b'
	Thou. cwt.	*Thou. cwt.*	*Thou. cwt.*	*Thou. cwt.*
Area 1	1,695	—43.147	2,515	—238.979
Area 2	3,020	—76.133	4,481	—421.680
Area 3	23,424	—573.413	34,636	—3,175.971
Area 4	454	—11.528	676	—63.848
Area 5	798	—20.302	1,188	—112.448
Area 6	9,401	—230.254	13,950	—1,275.312
Area 7	525	—13.229	781	—73.271
Area 8	282	—7.188	421	—39.812
Area 9	3,893	—97.774	5,977	—541.540
Area 10	1,528	—39.706	2,372	—219.920
Area 11	4,099	—103.155	6,314	—571.347
Area 12	10,117	—247.039	15,536	—1,368.277
Area 13	1,906	—48.538	2,942	—268.838
Area 14	5,246	—135.033	8,067	—747.907
Area 15	3,217	—80.941	4,792	—448.310
Area 16	13,180	—330.179	19,631	—1,828.764
Area 17	4,265	—108.890	6,381	—603.112
Area 18	3,141	—77.882	4,706	—431.369
Area 19	31,145	—764.698	46,387	—4,235.439
Area 20	9,206	—226.794	13,895	—1,256.147
Area E*	1,006	—26.257	1,503	—145.431
Area F	73,554	—1,766.981	114,911	—9,867.797

* For demand estimation, Areas E and F were added to the 20 production areas.

Appendix Table 2. Linear Programmed Milk Supply Functions, 20 Areas in the Northeast with 1960 Resource Base, No Area Price Differentials

Price	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8
				Thousand cwt.				
$2.80	4,879	3,624	7,200	7,191	5,617	*6,380	9,048	2,649
3.20	5,834	3,910	7,871	8,024	5,734	*7,193	9,669	2,714
3.60	6,443	4,304	8,893	8,443	6,341	7,204	10,310	2,801
4.00	7,001	4,683	9,635	9,504	6,814	8,849	11,811	3,157
4.20	7,050	5,059	10,221	9,913	7,603	9,161	12,679	3,317
4.40	7,285	5,286	10,509	10,081	7,857	9,783	12,857	3,504
4.60	7,480	5,505	10,887	10,393	8,443	10,424	12,935	3,899
4.80	7,651	5,511	11,369	10,453	8,454	10,660	13,062	4,004
5.00	7,843	5,716	11,928	10,601	8,871	11,423	13,716	4,065
5.20	8,265	5,800	12,648	10,981	8,933	12,345	13,872	4,116
5.40	8,442	5,829	12,908	11,360	9,036	12,464	13,880	4,185
5.60	8,521	5,853	13,924	11,479	9,072	12,532	14,140	4,241
5.80	8,603	5,910	14,267	11,497	9,212	12,550	14,304	4,287
6.00	8,958	6,073	14,420	11,570	9,385	12,752	14,416	4,287
6.20	9,129	6,091	14,694	11,666	9,422	12,769	14,426	4,287

Price	Area 9	Area 10	Area 11	Area 12	Area 13	Area 14	Area 15
				Thousand cwt.			
$2.80	16,426	17,668	24,080	0	21,448	17,045	16,595
3.20	16,729	19,325	25,251	8,664	23,469	28,188	21,040
3.60	17,979	20,982	29,075	13,228	26,090	29,306	22,190
4.00	20,909	22,779	30,580	16,309	28,784	34,287	24,949
4.20	21,637	23,232	36,091	16,605	30,026	35,287	26,501
4.40	21,969	23,774	36,415	17,398	31,123	36,134	28,060
4.60	23,926	24,179	36,925	19,173	31,974	36,520	28,697
4.80	25,032	24,331	37,473	21,940	32,379	36,938	29,090
5.00	25,647	24,604	37,648	25,139	32,632	37,088	29,277
5.20	25,694	24,872	37,697	25,835	33,179	37,986	29,577
5.40	26,253	25,065	37,910	28,378	33,179	38,019	30,518
5.60	26,385	25,065	37,910	29,345	33,304	38,260	30,940
5.80	26,434	25,065	38,052	29,807	33,563	38,300	31,032
6.00	26,527	25,065	38,618	30,409	33,586	38,412	31,126
6.20	26,621	25,349	38,722	30,613	33,608	38,489	31,173

* Estimated from the linear equation derived from Area 6 programmed results. $Q = 684.4 + 2034.2\ (P)$.

† Estimated from the linear equation derived from Area 19 programmed results $Q = 5{,}634.4 + 3{,}512.0\ (P)$.

Appendix Table 2. Linear Programmed Milk Supply Functions, 20 Areas in the Northeast with 1960 Resource Base, No Area Price Differentials — *(Continued)*

Price	Area 16	Area 17	Area 18	Area 19†	Area 20	Northeast Total
			Thousand cwt.			
$2.80	7,607	10,962	10,143	30,795	0	219,357
3.20	20,733	14,503	12,580	43,067	45	284,543
3.60	21,596	17,933	13,491	45,219	227	312,055
4.00	26,002	19,683	14,930	59,465	1,459	361,590
4.20	26,622	22,726	15,458	60,826	1,459	381,473
4.40	26,830	23,049	16,156	61,316	1,563	390,949
4.60	27,263	23,049	16,948	63,936	1,576	404,132
4.80	27,769	23,129	17,919	64,781	1,576	413,521
5.00	27,928	24,371	17,946	65,423	1,576	423,442
5.20	27,928	24,455	18,368	65,436	1,576	429,563
5.40	27,988	24,455	18,564	68,698	1,576	438,707
5.60	27,988	24,592	19,103	69,401	1,579	443,634
5.80	27,988	24,864	19,113	70,178	1,598	446,624
6.00	27,988	24,910	19,316	71,302	1,598	450,718
6.20	27,988	25,074	19,316	72,019	1,598	453,054

Appendix Table 3. Linear Programmed Milk Supply Functions, 20 Areas in the Northeast with 1965 Resource Base, No Area Price Differentials

Price	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
				Thousand cwt.			
$2.80	2,673	2,464	4,824	5,480	4,422	*4,447	7,291
3.20	3,196	2,659	5,274	6,090	4,508	*5,014	7,761
3.60	3,530	2,927	5,958	6,400	4,946	5,021	8,284
4.00	3,836	3,184	6,455	7,381	5,250	6,168	9,557
4.20	3,863	3,440	6,848	7,747	5,815	6,385	10,261
4.40	3,991	3,594	7,041	7,846	5,991	6,819	10,402
4.60	4,098	3,743	7,294	8,131	6,396	7,266	10,463
4.80	4,192	3,747	7,617	8,185	6,401	7,430	10,585
5.00	4,297	3,887	7,992	8,289	6,709	7,962	11,090
5.20	4,528	3,944	8,474	8,615	6,751	8,604	11,213
5.40	4,625	3,964	8,648	8,941	6,838	8,687	11,220
5.60	4,669	3,980	9,329	9,022	6,851	8,735	11,425
5.80	4,714	4,018	9,559	9,038	6,939	8,747	11,572
6.00	4,908	4,130	9,661	9,077	7,117	8,888	11,652
6.20	5,002	4,142	9,845	9,142	7,141	8,900	11,659

Appendix Table 3. Linear Programmed Milk Supply Functions, 20 Areas in the Northeast with 1965 Resource Base, No Area Price Differentials — *(continued)*

Price	Area 8	Area 9	Area 10	Area 11	Area 12	Area 13	Area 14
				Thousand cwt.			
$2.80	2,056	13,774	16,257	20,500	0	14,554	12,486
3.20	2,114	14,085	17,799	21,604	5,478	16,572	21,334
3.60	2,178	15,064	19,290	24,658	9,361	18,307	22,295
4.00	2,445	17,491	21,059	26,152	11,732	20,079	25,355
4.20	2,567	18,246	21,405	31,253	11,775	20,893	26,295
4.40	2,710	18,548	21,911	31,583	12,345	21,770	27,083
4.60	2,997	20,207	22,312	32,044	13,590	22,290	27,443
4.80	3,088	21,351	22,406	32,514	15,502	22,614	27,846
5.00	3,141	21,877	22,768	32,646	17,764	22,842	28,003
5.20	3,185	22,096	22,920	32,674	18,812	23,043	28,506
5.40	3,239	22,342	23,087	32,853	19,109	23,051	28,589
5.60	3,281	22,550	23,154	32,997	19,412	23,101	28,781
5.80	3,321	22,568	23,154	33,088	19,680	23,298	28,845
6.00	3,321	22,651	23,154	33,497	20,042	23,298	28,845
6.20	3,321	22,745	23,322	33,568	20,185	23,314	28,910

Price	Area 15	Area 16	Area 17	Area 18	Area 19†	Area 20	Northeast Total
				Thousand cwt.			
$2.80	12,366	5,879	8,329	9,124	22,906	0	169,832
3.20	15,673	15,912	10,943	11,646	31,332	30	219,024
3.60	16,579	16,554	13,680	12,049	32,855	150	240,086
4.00	18,614	20,050	15,041	13,921	43,496	967	278,233
4.20	19,644	20,541	17,397	14,128	44,280	967	293,750
4.40	20,796	20,688	17,634	14,812	44,865	1,036	301,465
4.60	21,140	21,410	17,634	15,596	46,730	1,045	311,829
4.80	21,545	21,425	17,704	16,501	47,343	1,045	319,041
5.00	21,714	21,521	18,613	16,527	47,843	1,045	326,530
5.20	21,908	21,521	18,682	16,948	47,853	1,045	331,322
5.40	22,619	21,566	18,682	17,108	50,484	1,045	336,697
5.60	22,915	21,566	18,784	17,637	51,060	1,047	340,296
5.80	23,021	21,566	18,983	17,816	51,630	1,059	342,616
6.00	23,027	21,566	19,021	17,827	52,546	1,059	345,287
6.20	23,092	21,566	19,141	18,422	53,133	1,059	347,609

* Estimated from the linear equation derived from Area 6 programmed results, Q = 684.4 + 2034.2 (P).

† Estimated from the linear equation derived from Area 19 programmed results Q = —5.634.4 + 3.512.0 (P).

APPENDIX B

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